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RESEARCH
AND
DEVELOPMENT
LECTURE SERIES

STABILIZED FRAGMENTS

BY

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STABILIZED FRAGMENTS

by M. B. Schaffer

This part of today's symposium should really be entitled "Fin-stabilized Fragments" since most of the current work on low-drag fragments is concentrated on finned shapes. I will mention briefly several unfinned shapes: first in connection with the canister development program (specifically spheres and cylinders, which are essentially unstabilized) and second, in connection with an anti-personnel warhead for guided missiles (specifically the so-called Alperstein or fish-tailed configuration which is drag-stabilized). I would also like to discuss briefly the method by which we propose to apply the lethality concepts of BRL to the design of canister ammunition.

At this point it might be advisable to consider generally the applications of fin-stabilized fragments to Ordnance. There are two broad classifications: projectiles with high remaining velocity and projectiles with low remaining velocity. Under the latter grouping come grenades and mines, on which there is apparently no current work. Under the high-remaining-velocity group, there are two sub-headings: indirect-fire weapons and direct-fire weapons. (See Figure 1.)

Let us consider these applications in detail in the order listed on Figure 1. First there is Armour Research Foundation, which was among the earliest in the field.

Armour Research Foundation

Armour Research Foundation in early 1951 was requested by OCO to investigate the feasibility of using a dart-filled, anti-personnel warhead for the 2.75" T131 Rocket, which was under development at the time. This high-velocity boosted rocket, which is normally an air-to-air weapon, was to be used in this application from air-to-ground. The study was made more or less informally without a contract and continued into the middle of this year. It was eventually dropped, since the contractual coverage did not materialize. As a result of its work, however, Armour Research Foundation can be credited with the following accomplishments:

1. Coining the term "flechette" for the darts. The dictionary defines a flechette as "a small steel dart with a vane or fluted shaft, to be dropped from an aircraft as a missile".

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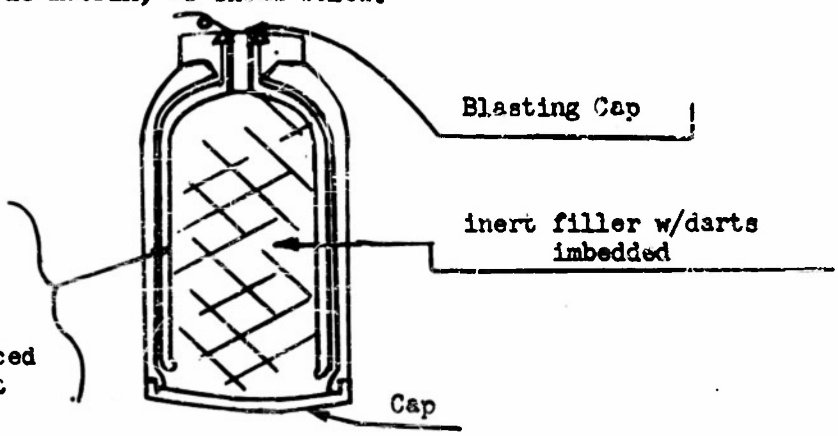
Strictly speaking, Armour Research Foundation was correct enough in its nomenclature for this application although its subsequent usage is not so easily justified.

2. Developing a satisfactory technique for mass-producing the darts. The evolution of the Armour Flechette is shown on Figure 2. The first of these designs was made in the following two ways: (a) Starting with .100" diameter wire stock two fins, one behind the other and 90° apart, would be pressed out in two separate operations (b) Starting with the same wire stock, one long fin would be pressed out and partially cut at its center, with the rear fin rotated 90°. Armour manufactured sufficient quantities of this design to load several warheads. The warhead contained 141 random-loaded flechettes imbedded in a plaster of paris matrix, as shown below.



During static tests, the flechettes dispersed well, but the last fin invariably broke off. On the basis of these preliminary tests, the flechette was redesigned (Figure 2). The three fins and the points of the flechette behind are stamped in a single operation. The wire diameter in this instance was reduced to .072" to accommodate the operation. Two methods of feeding the dies were investigated. The first, which was subsequently used for manufacturing large quantities, consisted of feeding the wire from a spool into the die; the second would feed standard finishing nails from a hopper into the die.

Static tests of this second flechette design were also conducted in a similar head. The results were that some fins broke off and almost all flechettes were deformed or bent in some way. Armour later developed several safeguards for dispersing the flechettes without deforming them. In general, these were: (1) shielding the primacord on the loadside with split tubing; (2) substituting rosin for the plaster of paris; (3) assembling the flechettes (in molds) in cylindrical bundles-all noses forward;

(4) placing the bundles in the head and filling balance of space with rosin. When so assembled the head, which weighed 1.74 pounds, could hold 500 seven-grain flechettes. About 8% of these would be deformed upon detonation. By zinc plating the flechettes, Armour eliminated small pieces of rosin that stick to the flechettes on breakup.

3. The other designs shown on Figure 2 were evolved from stability and drag tests run by Armour. Their stability tests were rather crude. They suspended a flechette at its center of gravity and directed the air stream of an electric fan at it. All the designs shown on Figure 2 passed this test with flying colors; they aligned themselves so that the noses faced the air stream. The drag tests consisted of loading single flechettes into a .410 gage shotgun and firing them nose forward. Fastax movies indicated the flechettes traveled toward the targets in a relatively stable fashion. Velocity measurements were also taken with the following results for the lower four designs shown on Figure 2:

Design No.	Mach No.	Relative Drag Coefficient
1	1.37	1.0
2	1.12	0.74
3	1.38	0.33
4	1.46	0.16

The reports do not state to what area or diameter the drag coefficients were referred. Presumably, they were all referred to the same area. The interpretation is then fairly obvious. The reduction in fin radius (which reduced the fin area by 42%) alone cut the drag to 1/3 its previous value; lengthening the cone point cut this again by 1/2. Armour's measurements were admittedly not too precise. As will be pointed out later, they did not determine the large losses in velocity due to yaw very near the muzzle. They were thinking in terms of launching the flechette nose forward only and thus did not concern themselves with decreasing the yaw and its rate of damping out. Of far greater significance was the technique they introduced for mass-producing this type fragment. Armour subsequently served as a supply source of the 7-grain flechette for many Ordnance facilities.

This, then, generally sums up the work done by Armour. They did conduct some additional flight tests of these heads at Aberdeen Proving Ground. In general, they were unsatisfactory due to fuzing difficulties. All this work is summed up in their progress reports on Project 90-811K entitled "Development of Aircraft Ammunition" (beginning with Report No. 22 dated November 1951). Since they had not yet attempted to select the best fragment weight, they used a flechette weighing about 7 1/2 grains throughout. In the middle of 1952, however, Armour made a special design study of a flechette-filled warhead for the 70 mm HEAA Rocket, T212, which in this application would be ground-to-ground. They theoretically considered flechettes of 7, 15, and 23 grains, using a 58 ft-lbs fatality criterion and "remaining velocity" curves prepared by International Harvester Company. Taking into account burnout times and fuzing errors, they calculated optimum burst heights and concluded that a 15-grain fragment would be best for this application. This work is summarized in a special report under Armour Research Foundation Project M033-2.

<u>Aircraft-Armaments, Inc</u>

Aircraft Armaments Inc. has had a contract with the Naval Research Laboratories (since 1951) to develop a relatively small caliber round of ammunition for use in existing air-to-ground and ground-to-ground weapons. The projectile is to contain fin-stabilized fragments which will be effective up to 300 yards. There are no reports available at Picatinny on this development. The little I can tell you now was learned at a recent symposium at OCO on stabilized fragments.

A 20 mm cannon was chosen as the first test vehicle. I can't tell you much about the projectile itself, except that it will contain from 15 to 50 flechettes, each weighing about 17 grains. A narrow dispersion pattern (10 to 20 mils at the 300 yard range) is anticipated.

In this application, the flechettes will obviously be fired nose first. Aircraft Armaments has therefore not concerned itself with extensive investigation into optimum flechette design with regard to location of center of gravity and center of pressure, i.e., stability, except in the following sense: Their initial firings were conducted by mounting single flechettes in heavier containers which discard near the muzzle. These firings resulted in drag measurements which were very high. It took considerable investigation to discover that the heavier discarding carrier was ploughing through and upsetting the flechette when it was fired. They eventually overcame this difficulty and succeeded in obtaining frontal drag coefficients as low as 0.2. In so doing, they varied the weight (7, 17, and 21 grains), the length to diameter ratio, and the number and configuration of fins. They finally decided on a length/diameter ratio of 24, a length of 2", 4 fins, and a maximum fin chord of 1/4". They also found that the cone angle and the surface roughness had considerable effect on the value of the drag coefficient.

Another problem that they ran into and apparently solved was that of excessive dispersion. By canting the fins from 1° to 3°, they met the dispersion requirement. Except for this and for the fact that there are four fins, the flechettes themselves have the general configuration of the Armour flechettes.

It is quite obvious that we should make every effort to get their reports for application to the rocket, guided missile, and canister programs.

<u>Arthur D. Little, Inc.</u>

A contract was placed with A. D. Little in July 1952 by Redstone Arsenal for development of a flechette-filled, anti-personnel warhead for the 4.5" T160E5 Rocket. This is normally a ground-to-ground weapon. The warhead weight is 18 pounds and the rocket spins at a rate of 15,000 rpm at detonation. A. D. Little spent the first 6 or 7 months of its contract making literature searches, visiting government installations, gathering as much information as it could on the general subject. Also, during this time they made generalized studies of the problem as they then saw it. Using a 58 ft-lb fatality criterion, they prepared remaining velocity curves (using assumed form factors) for flechettes and spheres. In addition they investigated the following basic warhead designs: (a) a flechette-filled warhead with no explosive dispelling the charge, (b) a flechette-filled warhead with an explosive to add velocity to the flechettes, and (c) a sphere-filled warhead with and without matrix. On the basis of this work they came to several conclusions, some of which proved inapplicable when the lethality criterion was later changed. These conclusions were:

(1) Without some sort of explosive in the warhead to impart additional velocity to the fragments, no significant improvement in lethal area over existing designs would be obtained. (When the criterion was changed, they recognized that considerable improvement could be obtained because at the same energy level flechettes have much greater penetrating power than balls.) They nevertheless spent considerable effort in designing warheads which would impart additional velocity to the flechettes. They are still working on a device of this nature which they call a "nose ejection head."

(2) Since they expected the rate of spin of the rocket to be too low to produce desired dispersion, they spent considerable time devising ways to obtain adequate dispersion of the missiles. In this phase, they did much theoretical work on canted flechette fins.

When the objectives of this rocket problem were further explained to A. D. Little's satisfaction, their performance on the project improved considerably. Beginning with the early part of this year, they took up where Armour left off and have since contributed much. Incidentally, the lethality criterion they eventually adopted was a terminal velocity of 500 ft/sec, which is equivalent to 9 ft-lbs of energy. They finally concluded that the warhead should contain 9000 3-grain flechettes, that the launching velocity of the flechettes should be about 600 ft/sec, and that the optimum burst height should be 100 feet. The estimated lethal area obtained from this design will be 15,000 square feet which compares to about 2500 square feet for present designs. They are considering several methods for launching the flechettes, including the method used by Armour which now appears most promising to them.

Little's chief contribution has been their theoretical analysis of the flechette shape and their subsequent stability tests which are still continuing. Little early recognized that the greatest gain, as far as low drag is concerned, has already been made in going from other shapes to the flechette. They therefore decided that the only question remaining was that of achieving adequate stability for the flechette. After considering wind tunnel tests and carefully reviewing all the available literature, they concluded that fin-first single flechette firings, with velocity, yaw, and penetration measurements, would tell the complete story. If the flechettes righted themselves within a short distance from the muzzle without losing much velocity, the fragment would meet the requirements. Since the best measure of the ability of a fragment to quickly damp out yaw is the distance of the center of gravity from the center of pressure, Little prepared twelve flechette designs (shown on Figure 3) and theoretically evaluated them (considering varying fin lengths and body lengths) for the optimum shape.

Without going into too much detail, I will rapidly go through these designs:

1. Design 1 is basically the Armour, 3-finned flechette. The center of gravity of this design is at the geometric center (by method of manufacture). The center of pressure is shifted to the rear by the fins. The theoretical optimum fin length and radius are shown on the sketch.

2. Designs 2 and 3 contain 4 fins and weighted noses, but the calculations indicate the distance between the center of gravity and center of pressure is less than that for design 1.

3. Designs 4 and 5 are an attempt to move the center of gravity forward by using a bi-metal design with a forward portion of steel crimped to an aluminum tail. These will obviously be difficult to manufacture.

4. Design 6 presents a much larger fin area, but theoretically this is about as stable as design 1. Note, however, that the much sharper cone nose should considerably reduce the drag. A second design of this configuration, 6a, with the nose angle changed to 30° shows considerable theoretical improvement in stability.

5. Design 7 represents a different approach. It is an attempt to quickly eliminate end-over-end tumbling by providing fins in the forward section.

6. Designs 8, 9, and 10 have been developed from a family of designs for each (the body and fin lengths were varied). The relative dimensions shown were found to be optimum. This configuration appears to be very desirable from a stability standpoint.

7. The bi-metallic design shown here (with no number) is theoretically 20% more stable than the best all-steel design.

8. Design 11 has very recently been proposed and not yet fully theoretically evaluated. It appears promising from a manufacturing, handling, and packing standpoint.

On the basis of their theoretical evaluation, Little chose for testing designs 6a, 7a (a modification of 7 with the rear fin thickness reduced to 0.080), 8, and 10, as well as the Armour design (the last because it is available). Because dies for these shapes are expensive, the initial samples were manufactured by tool-room methods. After running into the same difficulties that Aircraft Armaments did (interference between carrier and flechette) the problem was eventually solved by using a carrier developed by Watertown Arsenal. Satisfactory firings and data have nevertheless been obtained for the Armour flechette, designs 6a and 8 with the results shown in Figure 4. Firings were conducted both fin-first and nose-first and both subsonically and supersonically. All designs stabilized within 100 feet except 6a, fired backwards and supersonically. As predicted, design 8 stabilized most rapidly and consequently showed least drag both over the entire 100 feet and over the last 50 feet. Drag coefficients for the Armour flechette are about as predicted (based on work done at this Arsenal and International Harvester Co.) when fired nose first and subsonically. It appears that A. D. Little will just about meet their requirement (800 ft/sec initially and 500 ft/sec at 100 ft) with Design 8 fired fin first. (This is equivalent to a random pack.) They still must, of course, solve two major problems: a. Mass production of this design, and b. A technique for dispersing randomly loaded flechettes without damaging them or for overcoming a flechette handling problem if the flechettes must be stack-loaded in the warhead.

Little is continuing the tests on the designs shown here and the balance of the results should be available shortly. It is evident that tests of this nature (combined with the type of theoretical evaluation done) are basic in any ammunition development which uses flechettes. The work done by A. D. Little should eliminate much testing of a similar nature by Rheem and International Harvester Company.

Rheem Manufacturing Company

Let us now consider Rheem Manufacturing Company, which has a Picatinny contract for development of an anti-personnel warhead for the Honest John and Corporal Guided Missiles. This development is in the early stages and not too much can be said about it. Therefore, I will just give the vital statistics and summarize the contemplated plan of attack.

The warhead for these missiles is designated T40 and will weigh 1400 pounds. The guided missiles themselves are high-altitude, high-velocity, very low-spin or zero-spin projectiles. The development contract was placed in July 1953 with the understanding that the basic fragment design would be supplied by Ballistic Research Laboratory. Since this BRL design hasn't materialized to date (and the indications are that it never will), Rheem's contract is currently being supplemented to permit them to design their own basic fragment.

The little work accomplished to date in this direction has been based on a 58 ft-lbs fatality criterion. Rheem has recently been advised that several designs will be required (based on various criteria, at least one of which will be a wound-ballistics criterion). The plan is to submit the samples to the Medical Corps for evaluation and let them decide which is most effective. The indications are that a flechette of from 12 to 15 grains will be required.

Rheem has also been considering the so-called Alperstein Shape, which is shaped something like a "fish".

It is not low-drag, but drag-stabilized. It has excellent packing qualities (see diagram) and should be relatively easy to manufacture and handle. Further, it should be less susceptible to damage than a flechette. However, its overall effectiveness remains to be seen.

Rheem's work will be reported under Projects TA2-3007 (Corporal) and TU2-1029 (Honest John), the reports of which will be available at Picatinny Arsenal. Rheem's problems are of course essentially the same as those of Armour and Little except that the projectiles are low or zero spin (1 1/2 rpm maximum). Consequently, either very high burst heights, or an explosive charge, or canted fins will have to be used to get adequate dispersion.

Ballistic Research Laboratory

BRL is generally considering all the applications of stabilized fragments to Ordnance and correlating the basic wound-ballistics data of the Medical Corps. Insofar as their interest in flechette-filled artillery projectiles is concerned, they are not, to my knowledge, doing any actual design. They have, however, made generalized studies such as the following for 105 mm projectiles:

Projectile	Maximum Lethal Area	Lethal Area / Projectile Weight
PD Fuze	200 ft^2	6
VT Fuze	2,000 ft^2	60
Flechette-filled shrapnel	20,000 ft^2	600

A flechette-filled artillery projectile is thus theoretically ten times more effective than the most effective HE projectile. This is due to a combination of factors: (1) All the dispersion from shrapnel is forward and directed at the target, (2) Flechettes are low-drag fragments and arrive at the target with higher remaining velocities, (3) Flechettes have greater penetrating power and high wounding and killing power.

Midwest Research Institute - Watertown Arsenal - ORDTS

Midwest Research Institute has had a contract with ORDTS (since late 1952) for development of three weapons capable of firing multi-projectiles from a single cartridge. Two of these weapons, a 20 mm and a .22 caliber, are to fire spin-stabilized projectiles. The third weapon, whose bore diameter has not ~~as yet~~ been established, is to fire fin-stabilized projectiles (i.e. flechettes) and is to be a shoulder-fired weapon. The progress on all three weapons, as of October 1953, is summarized in a Midwest Summary Report entitled "Design of Reloadable Multi-Projectile Cartridge Weapons and Ammunition for Army Field Forces Use", MRI Project No. 833-E-65.

The flechette development is in the early stages. Briefly, the plan of attack is as follows: Two weapons are under consideration. The first will fire a multitude of flechettes simultaneously in a close pattern (14 mils at 200 yards, which is equivalent to an 8.4 ft circle). The striking velocity at 300 yards is to be 1000 ft/sec. The present plan is to use a .12 gauge shotgun, if possible.

The second weapon will fire a single flechette with the following specifications: A striking velocity of 4000 ft/sec at a 300 yard range. The accuracy at this range is to be 1 mil (circle 0.9 ft in diameter). Recoil is to be no greater than that in the M1 Carbine.

The specifications for both weapons were evolved from tests conducted by Mr. Bird of ORDTS at the Watertown Arsenal test range, using 7-grain flechettes in a .12 gauge shotgun.

In addition to establishing the requirements for the weapons just mentioned, Watertown Arsenal and Mr. Bird succeeded in developing a method for firing both single projectiles and multi-projectiles from small caliber weapons. This, therefore, to a large extent, has solved one of Midwest's problems (as well as one of Aircraft Armaments problems).

Figure 5 shows the general configuration of the cartridge they are contemplating. On the left you see a plastic sabot loaded with 52 flechettes (all nose forward). In the center is the same sabot without the flechettes. On the right, you see a conventional 12 gauge shotgun shell. Figure 6 again shows the sabot and the flechettes. Figure 7 shows a sketch of the flechette now contemplated. The dimensions shown are relative. As you can see, it is basically the Armour flechette, except it has four fins with square trailing edges. The leading edges, not shown, will be sharp to reduce drag. I think they are a little optimistic about the shape of the ogive (as far as manufacturing methods). This flechette will be used for the initial tests of the single projectile design. I believe they will try the same shape in the multi-projectile weapon if it proves satisfactory. Midwest Research Institute's problem is therefore simply that of refining the basic design already developed by Watertown Arsenal. Figures 8 through 11 show the work done at Watertown Arsenal. They are shadowgraphs of the Armour flechette fired singly, supersonically and nose first. (The last three show the back of the fins cut off so that the fins will not dig into the sabot upon setback.) Figures 12 through 16 are shadowgraphs of various multi-missile projectiles. All shots were taken very close to the weapon.

International Harvester Company

International Harvester Company, under a PA contract, has been developing canister ammunition for 40, 57, 75, 90, 105, 106 and 120 mm weapons (including guns, howitzers, and rifles) since late 1950. A canister is an anti-personnel round of ammunition designed specifically for defeating "human-wave massed attack" tactics of the enemy. It therefore must be capable of launching with a single shot as many lethal missiles as possible over as wide an area and for as great an effective or lethal range as possible. In very general terms, the canister functions as follows: the fragments are loaded into a relatively thin-walled container to which a high spin is imparted, upon firing, by a conventional-type rotating band. The container is slit in four places, 90° apart and longitudinally, in such a way that the canister walls, immediately after leaving the weapon peel back (as a banana) and release the charge of fragments. The fragments are thus dispersed within the volume of a cone, the angle of which depends only on the rifling twist of the weapon.

The design work has progressed from the use of stacked cylinders (or slugs) to spheres and now to the use of flechettes as filler. The stacked slugs were used in an attempt to overcome excessive weapon wear caused by the older type canisters used in World War II, which used lead or steel balls. (High set-backed forces on these older canisters resulted in hydraulic pressures on the walls of canisters and caused buckling within the weapon tube.) After perfecting the slug-type canister, attention was again turned to using spheres (which obviously have much lower drag than randomly tumbling slugs). By varying such things as wall thickness, slit length, etc., designs containing these spheres, without any matrix, were prepared and successfully tested. As predicted, the effective ranges of these canisters showed considerable improvement over the slug-loaded canisters. Since the obtainable ranges were, however, still far short of what the using services (with the exception of the Marines) would accept, attention was turned to the use of flechettes as filler. As an example of the advantage to be gained in going from slugs to spheres to flechettes, consider the following comparative effective ranges for the 105 mm Canister for Rifle, M27:

Slugs:	275 ft
Spheres:	400 ft
Flechettes:	900 ft (estimated)

We have been trying to supplement Harvester's contract since December of last year for development of a flechette-filled canister in the 75 mm caliber to serve as a prototype. Owing to low priorities and lack of funds, this supplement is not yet finalized and so Harvester has never been in a position where they can give their full attention to the problems involved. With Picatinny's authorization, however, they have made considerable progress in the development of what we call a "functional" canister; i.e., one which will launch the flechettes satisfactorily into free flight. Briefly, they first considered random-loaded canisters (without a matrix) and also designs containing "chains of flechettes", also without matrix. Since the 7-grain Armour flechette was available, it was used for the first tests. (The projectile for the 75 mm caliber weighs 14.7 lbs and the initial designs contained about 7000 flechettes.) Both of these designs proved unsatisfactory, upon test, because the high set-back forces which are built up while the canister is accelerating in the guntube caused the flechettes to become deformed, bent, and mangled. (See Figure 17) Obviously, in the condition in which you see these flechettes, none of them stabilized and penetrated the targets as desired.

The next step was therefore to design a projectile which would release its flechettes without deforming them. Harvester prepared six designs (designated T30E8 thru T30E13) which we are now preparing to test at Jefferson Proving Ground. A typical design (Figure 18) contains so called "compartments" or "layers" of flechettes. Each compartment contains closely stacked flechettes so placed as to best be able to withstand the very high setback forces (about 150,000 lbs on the bottom layer). They are also enclosed by a supporting column which increases in thickness as it progresses down the canister to withstand the progressively higher loads. The top two layers with the lowest loads have plastic supports. Harvester arrived at these designs by conducting static compression tests in compression machines. Some of the designs contain rosin and rubber-based matrix materials to help absorb the load. Others contain flechettes stacked with all noses forward to facilitate stabilization.

In general, there will be numerous problems involved in designing canister ammunition with flechette loads;

(1) Packaging and launching the flechettes without damaging them so that their characteristics in free flight will be those of low-drag, stable projectiles. We feel that the present series of designs is well along toward solving this problem.

(2) Stacking the flechettes within the canister so that an efficient space-weight relationship is obtained. The T30E8 - 13 canisters have payloads varying from 40 to 60% of the total projectile weights.

(3) Designing a flechette shape which strikes an optimum balance between stability (quick damping of large yaw angles) and drag. Harvester has done little in this

direction since dies for flechettes and test range facilities are expensive and they are not, as yet, covered by contract. We will, of course, benefit greatly from the work done by A. D. Little, although it must be remembered that they are concerned with ranges of about 100 ft and we need remaining velocity information for ranges up to 2000 feet. Midwest should provide us with some information in this direction, since they have a similar requirement. Watertown Arsenal has helped somewhat, but their range is only 300 feet long. We are therefore including in Harvester's contract a provision whereby they can conduct their own flechette firings at a test range they have set up at Booneville, Ind. In addition, we have made a theoretical investigation of flechette shapes (here at PA) assuming zero yaw, and will publish this in the form of a report.

(4) Developing methods whereby the various flechette shapes can be economically mass produced and packaged into the canister. This is probably the most serious problem facing all the contractors previously discussed. Harvester has made some progress in this direction. They have succeeded in die-producing some of the Armour flechettes using 1045 steel instead of 1010 steel. (This should prevent some deformation). They are currently looking into the needle-manufacturing industry for any information they can uncover from that source. They are also looking into the packaging problem. To date, they have succeeded in devising a satisfactory method whereby limited quantities of flechette-filled canisters can be assembled with reasonable economy. This problem will need, however, considerably more attention before production quantities can be taken on (especially some of the shapes proposed by A. D. Little.)

(5) Finally we must solve the problem of a good lethality criterion for canister ammunition. We have made considerable progress on that here at PA. We must also devise a good method for evaluating the effectiveness of flechette-filled canisters. Formerly, we used penetrations in a 1" pine board for evaluating slug- and sphere-filled canisters. A reasonable case can be made for this if we can control the strength (i.e., hardness) of the target materials. For flechettes, however, this method will probably prove totally inadequate.

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FIGURE 1

Applications of Flechettes to Ordnance

APPLICATION	GOVERNMENT FACILITY	R & D CONTRACTOR
A. High Remaining Velocity		
1. Indirect Fire		
a. Aircraft Rockets (boosted and non-boosted)	OCO - ORDTU	Armour Res Foundat
	Naval Ordnance	
b. Aircraft Cannon (small caliber)	BRL	Aircraft Armaments, Inc.
c. Ground-fired Rockets (boosted and non-boosted)	Redstone Arsenal	A. D. Little, Inc.
	BRL	
d. Guided Missiles	Picatinny Arsenal	Rheem Manufacturing Co.
e. Artillery Projectiles		
(1) Total Dispersion (HE)	BRL	
(2) Forward Dispersion (Shrapnel)	BRL	

*Presently Inactive

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FIGURE 1 (cont)

Applications of Flechettes to Orndnace

APPLICATION	GOVERNMENT FACILITY	R & D CONTRACTOR
2. Direct Fire	OCO - ORDTS	
a. Small Arms (Shotgun & Rifles)	Frankford Arsenal	
	Watertown Arsenal	Midwest Res Institute
b. Artillery (Canister Ammunition)	Picatinny Arsenal	Int'l Harvester Co.
	Watertown Arsenal	Victory Plastics Co.
B. Low Remaining Velocity		
1. Grenades		
2. Mines		

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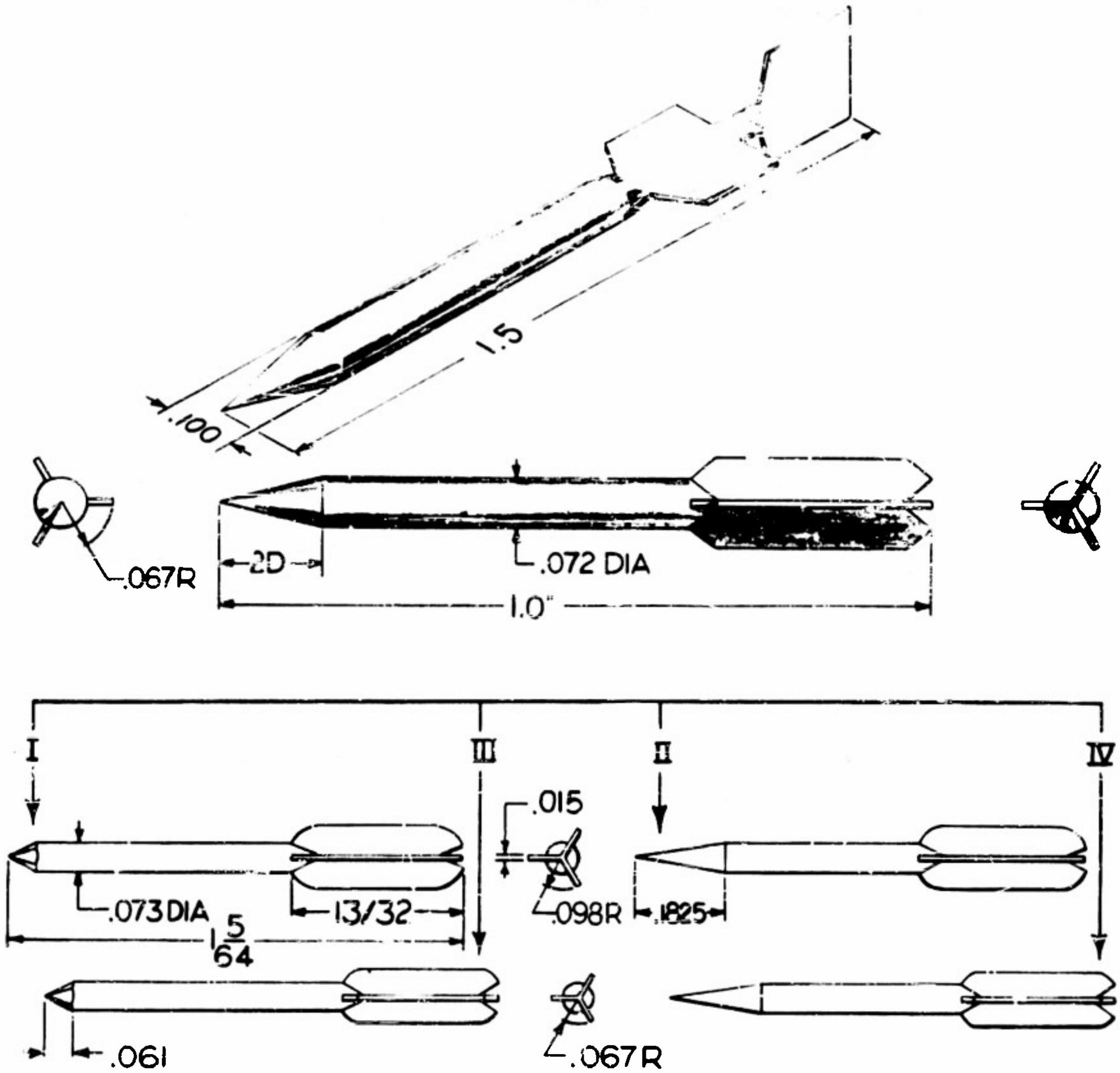
FIG.2



DESIGNS II, III, & IV HAVE SAME BODY DIAMETER, FIN LENGTH, AND OVERALL LENGTH AS DESIGN I

EVOLUTION OF ARMOUR FLECHETTE

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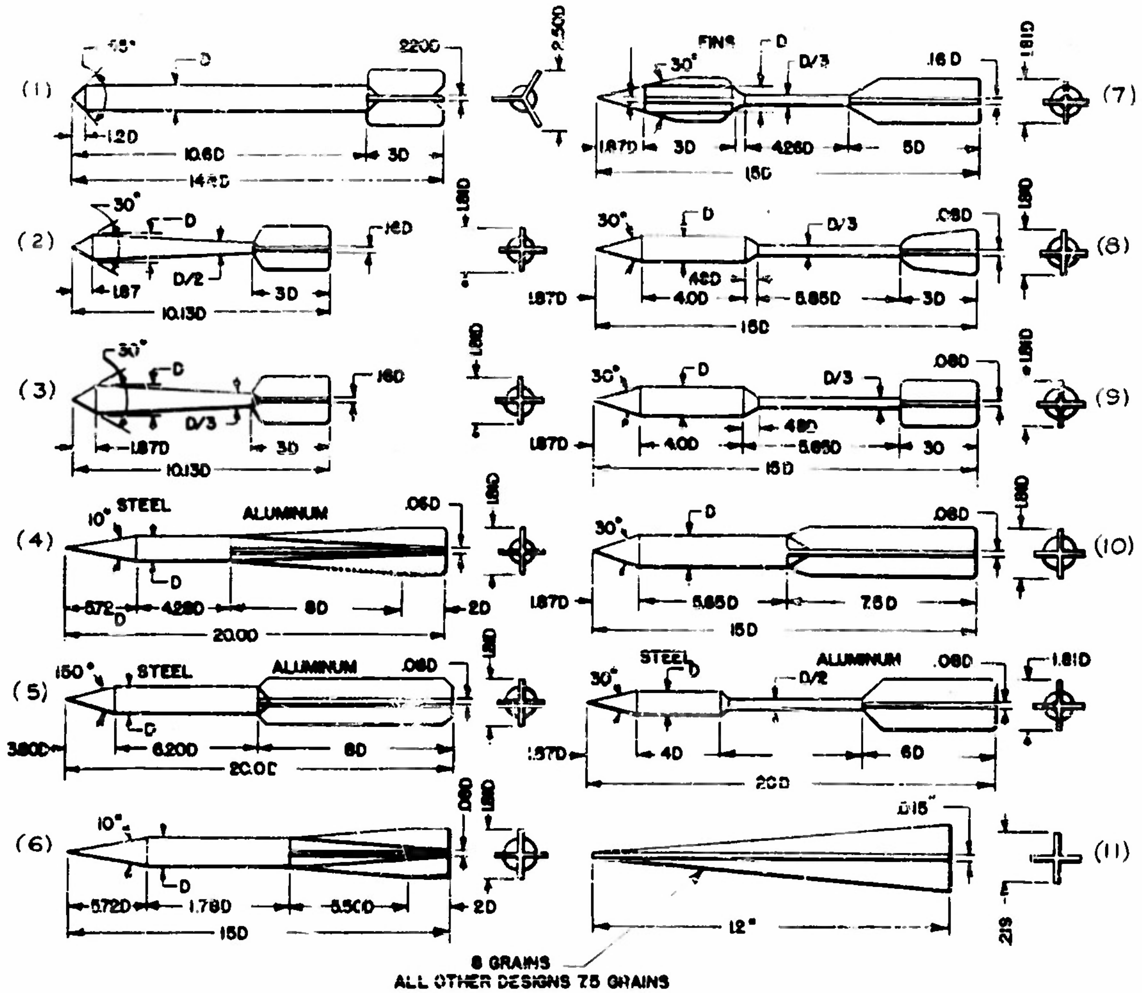
FIG.3



A.D. LITTLE FLECHETTES

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FIGURE 4

A. D. Little Flechette Firing Data

Design	Velocity (ft/sec) Range 0'	50'	100'	(Avg of 4-6 firings) Angle of Yaw (°) Range 25'	50'	75'	100'	Avg Drag Coef (100')	Avg Drag Coef (50-100')	Remarks
Tail-first, subsonic										
3-fin	920	320	280	62	29	17	10	6.5	2.8	Stab 70'
6A-1	710	280	145	51	29	25	—	6.0	2.4	Stab 70'
8-1	640	380	360	16	6	2	—	3.1	0.7	Stab 50' Pen 1¼" cel.
Tail-first, supersonic										
3-fin	1530	630	560	53	18	18	15	6.1	1.8	Stab 70'
6A-1	1340	690	440	37	37	36	36	7.3	3.3	Did not stab
8-1	1450	910	870	18	4	7	—	2.9	0.7	Stab 50'
Point-first, subsonic										
3-fin	540	490	480	2.5	2	0	0	1.1	0.4	Stable Pen 2¼" cel.
6A-1	530	490	480	4	3.5	2.5	0	.9	0.5	Stable Pen 2¼" cel.
Point-first, supersonic	1320	1180	1120	1.6	1.2	0	0	1.6	1.2	Stable Pen 8" cel.

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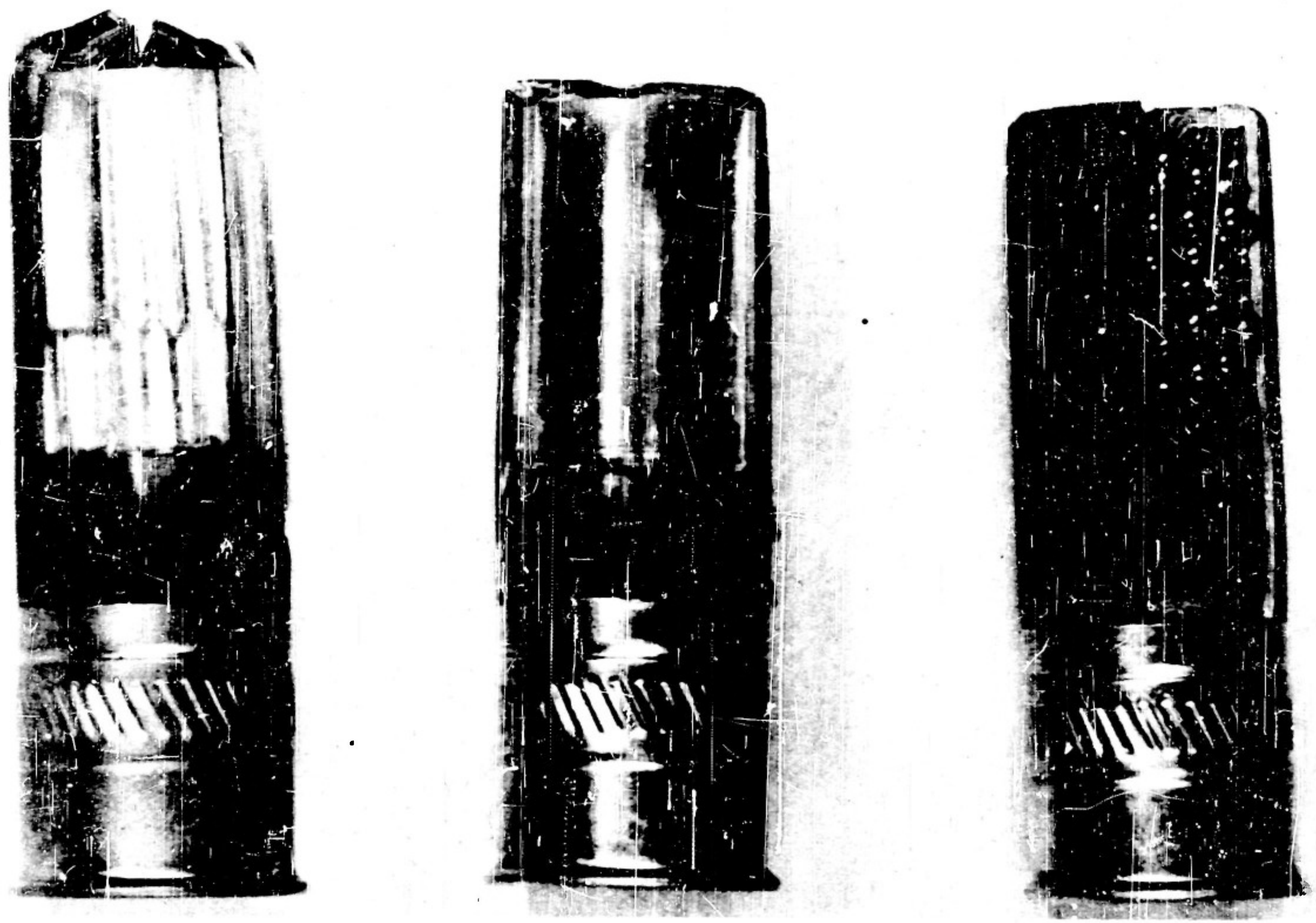

Fig. 5 - Sectional Views of 12-gauge Rounds. Conventional Round on Right; 52 Flechette Round on Left; Plastic Insert without Flechettes in Center.

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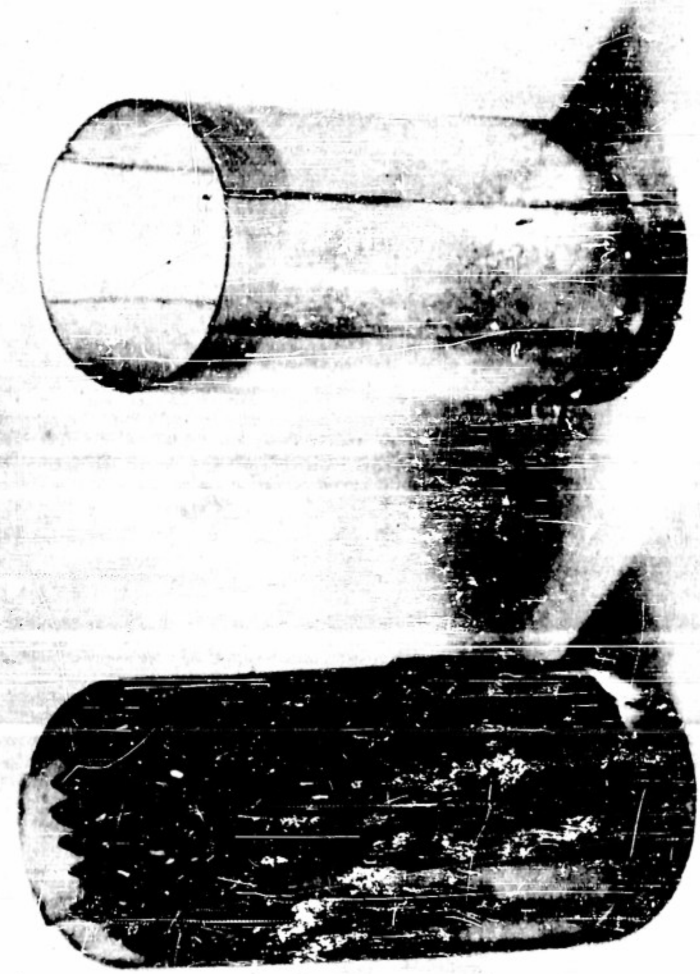

Fig. 6 - Plastic Sabot Containing 32 Flechettes

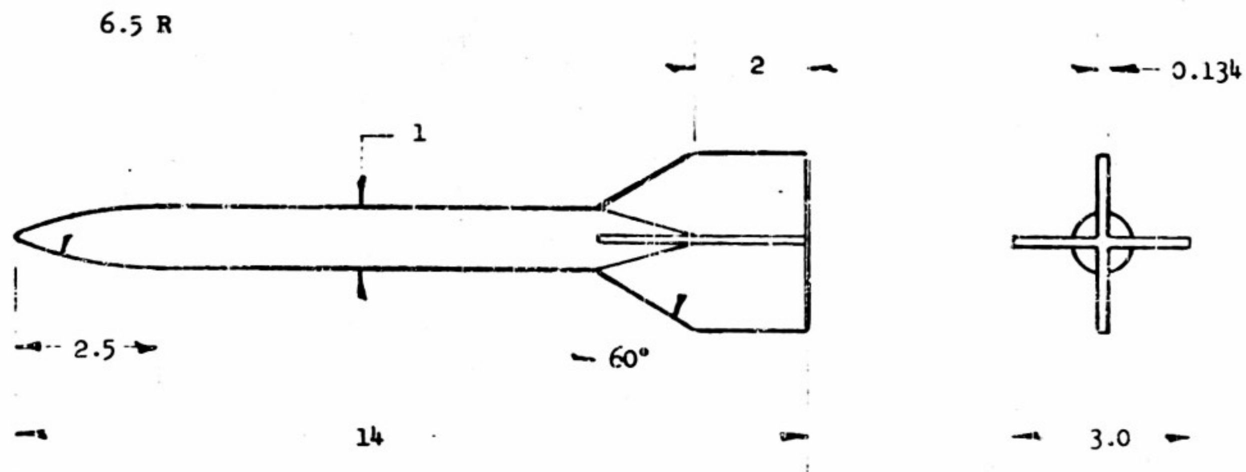

Fig. 7 - Recommended Design for Small Caliber Fin-Stabilized Projectiles.

Note: All dimensions in calibers.

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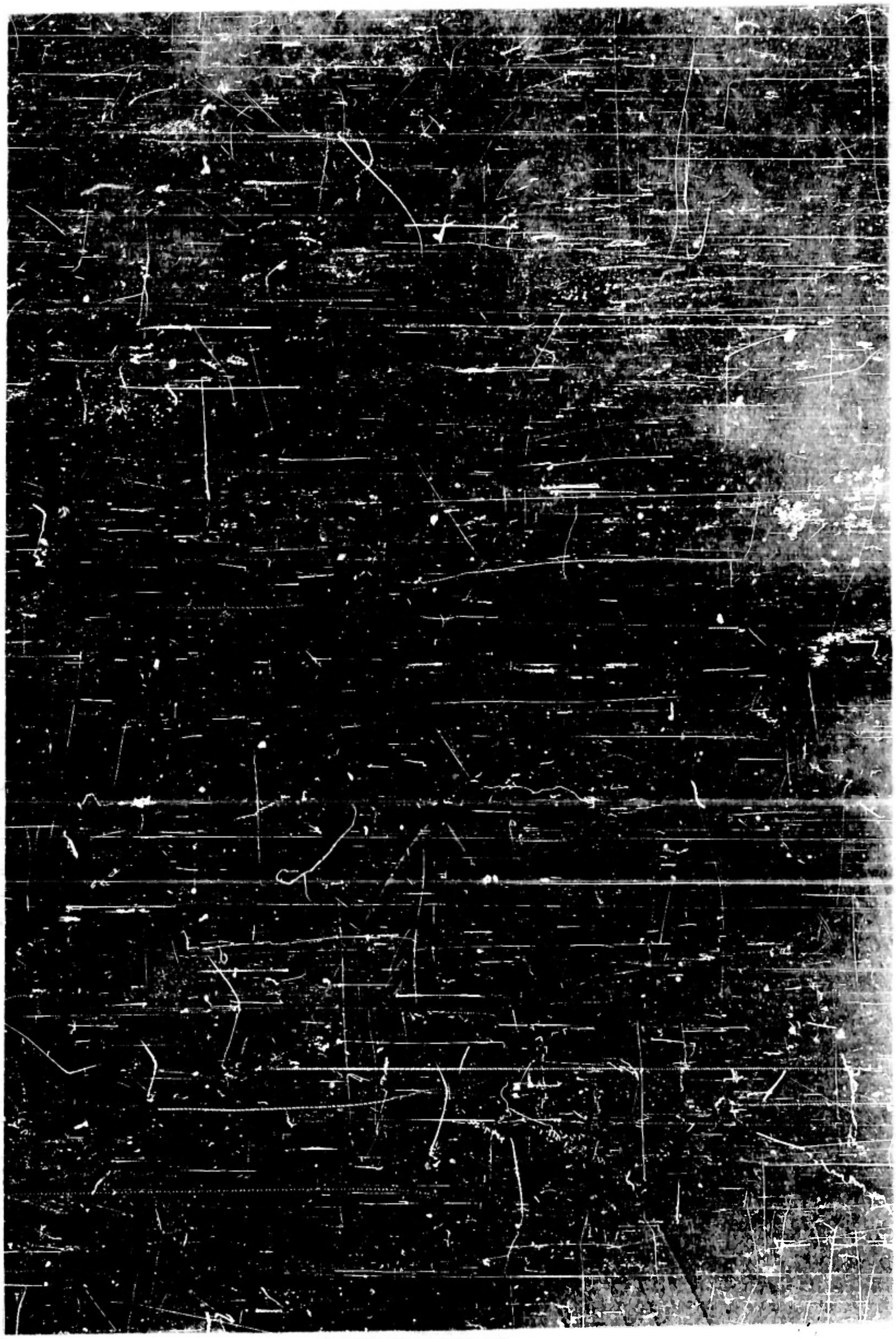

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FIGURE 8 - STANDARD FLECHETTE AT 10 FEET DISTANCE FROM THE MUZZLE OF THE GUN TUBE. VELOCITY - 2660 f/s.

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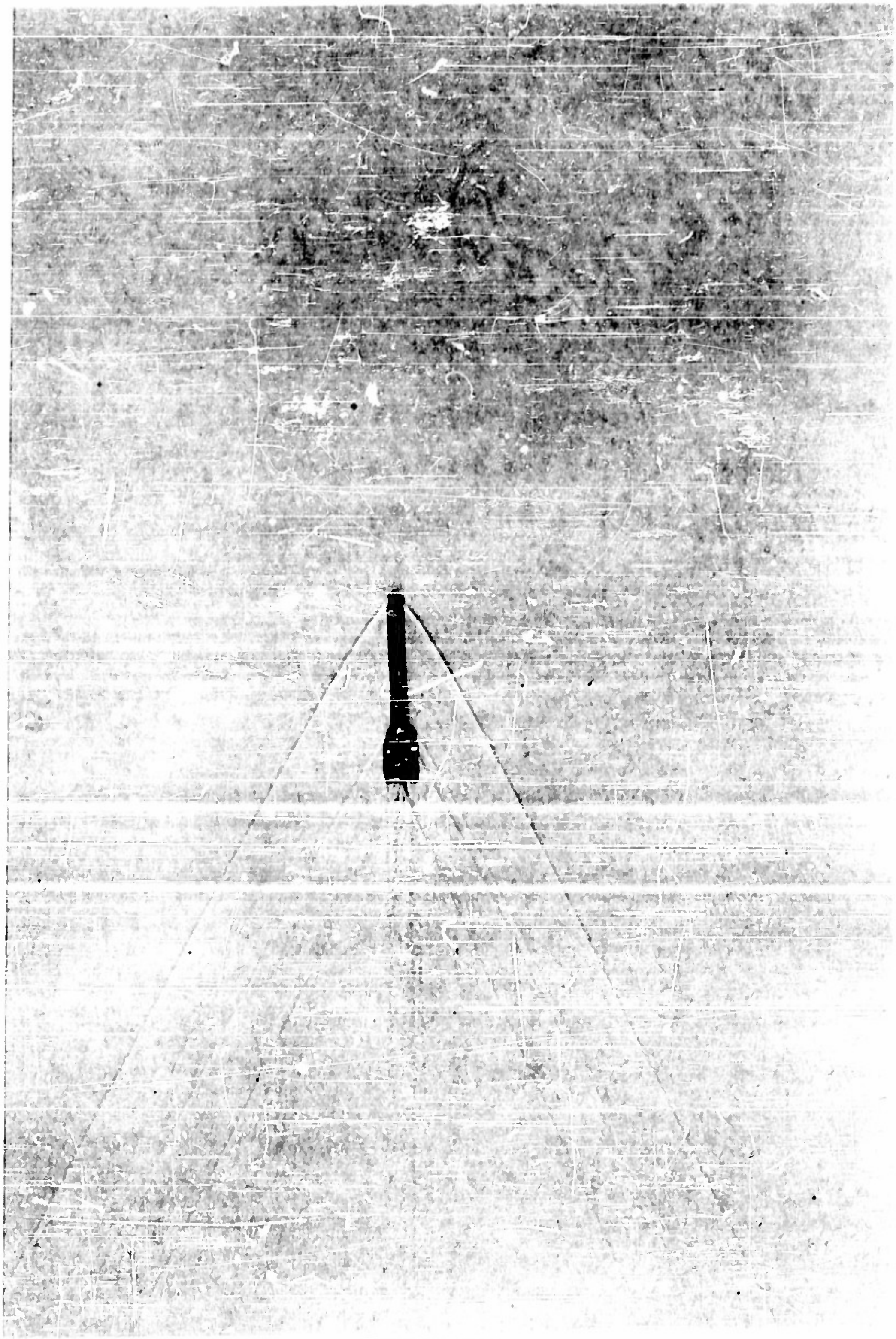

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FIGURE 9 - MODIFIED FLECHETTE AT 10 FEET DISTANCE FROM THE MUZZLE OF THE GUN TUBE. VELOCITY - 2655 F/S.

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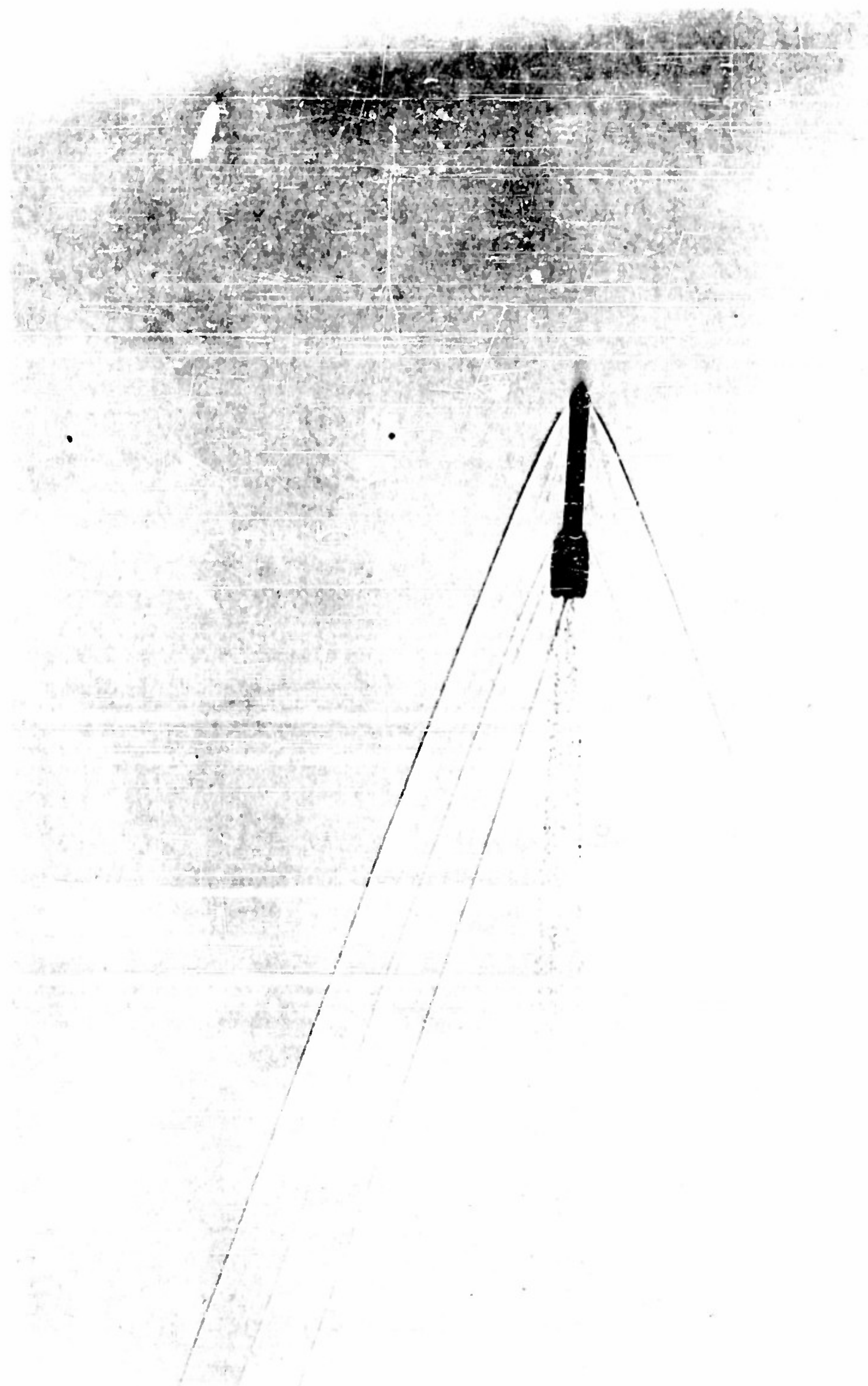

WATERTOWN ARSENAL LABORATORY

FIGURE [illegible] - MODIFIED FLECHETTE AT 10 FEET DISTANCE FROM THE MUZZLE OF THE GUN TUBE. VELOCITY - 3495 F/S.

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FIGURE [illegible] - MODIFIED FLECHETTE AT 10 FEET DISTANCE FROM THE MUZZLE OF THE GUN TUBE. VELOCITY - 3640 F/S.

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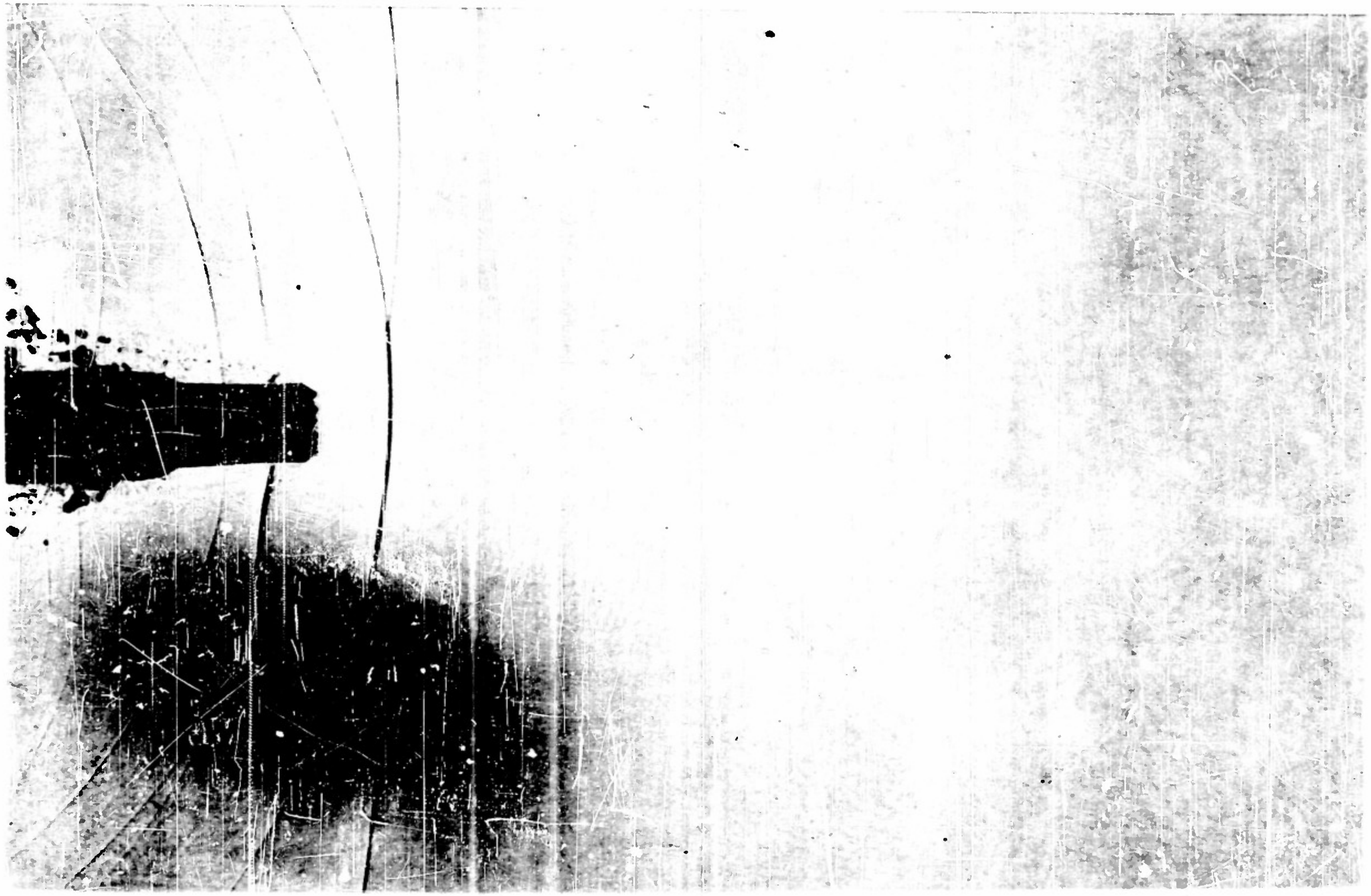

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FIGURE 12 – EXPERIMENTAL CALIBER 0.528" MULTI-MISSILE SHOT, CONTAINING 13 FLECHETTES, SHOWING ARRANGEMENT AT 12 FEET DISTANCE FROM THE MUZZLE OF THE GUN TUBE. VELOCITY – 1100 F/S.

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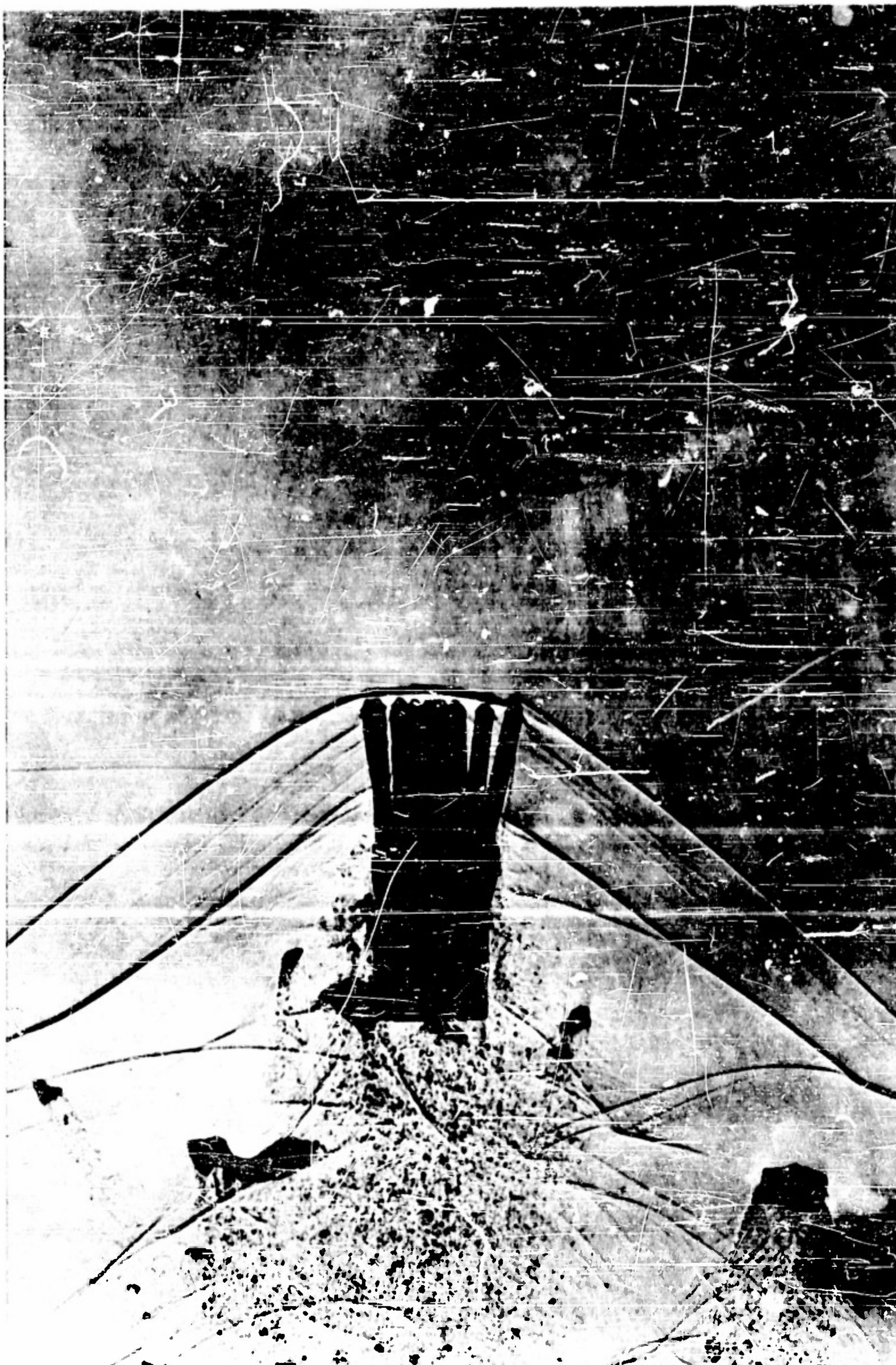

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FIGURE 13 – EXPERIMENTAL CALIBER 0.520" MULTI-MISSILE SHOT, CONTAINING 13 FLECHETTES, SHOWING ARRANGEMENT AT 12 FEET DISTANCE FROM THE MUZZLE OF THE GUN TUBE. VELOCITY – 1900 F/S.

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FIGURE 14 – EXPERIMENTAL 12 GA. MULTI-MISSLE SHOT, CONTAINING 26 FLECHETTES, SHOWING ARRANGEMENT AT 3 FEET DISTANCE FROM THE MUZZLE OF THE GUN TUBE.

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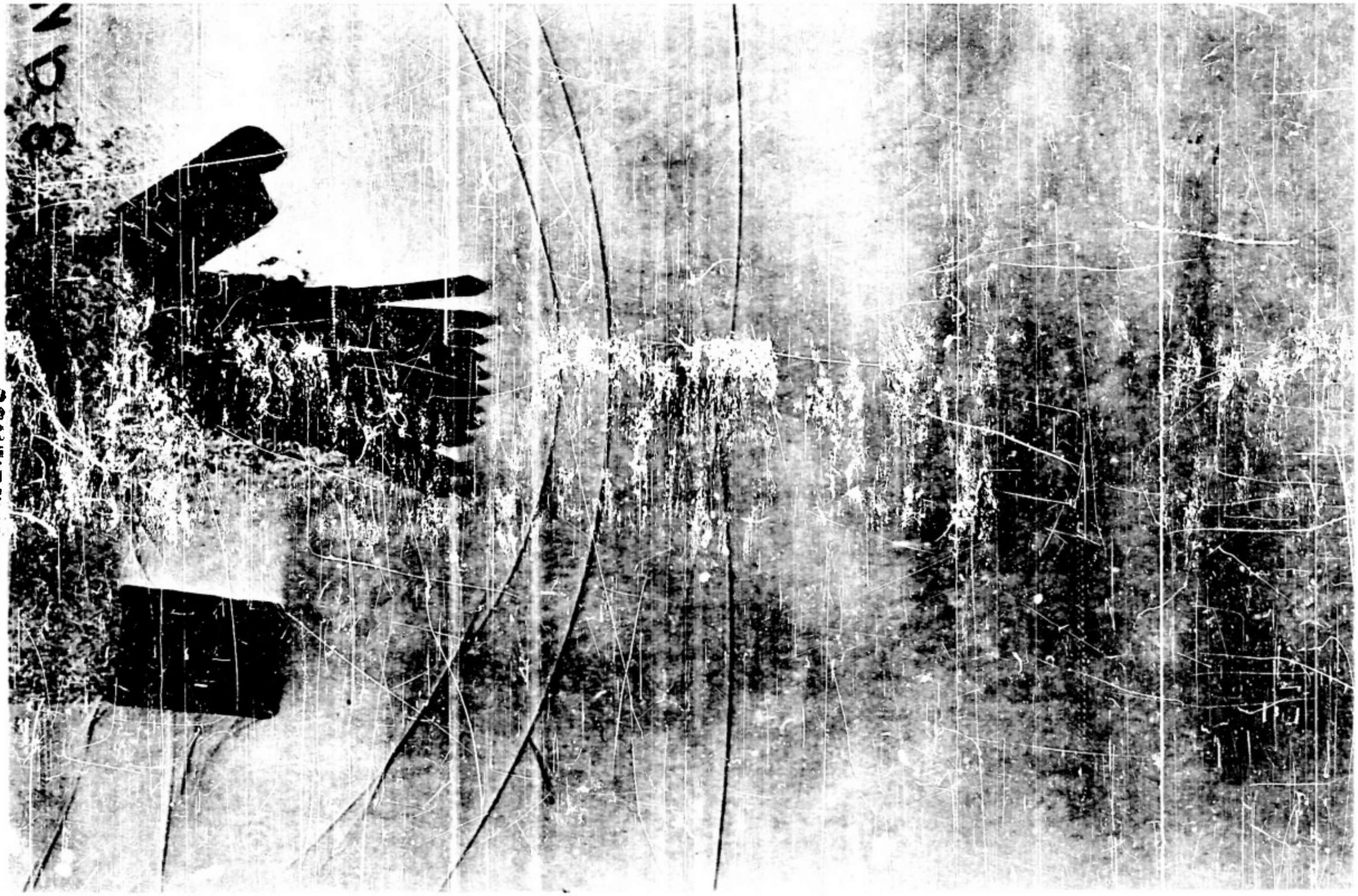

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FIGURE 15 - EXPERIMENTAL 12 GA. MULTI-MISSLE SHOT, CONTAINING 26 FLECHETTES, SHOWING ARRANGEMENT AT 4.5 FEET DISTANCE FROM THE MUZZLE OF THE GUN.

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FIGURE 15 - EXPERIMENTAL 12 GA. MULTI-MISSLE SHOT, CONTAINING 25 FLECHETTES, SHOWING ARRANGEMENT AT 3 FEET DISTANCE FROM THE MUZZLE OF THE GUN TUBE.

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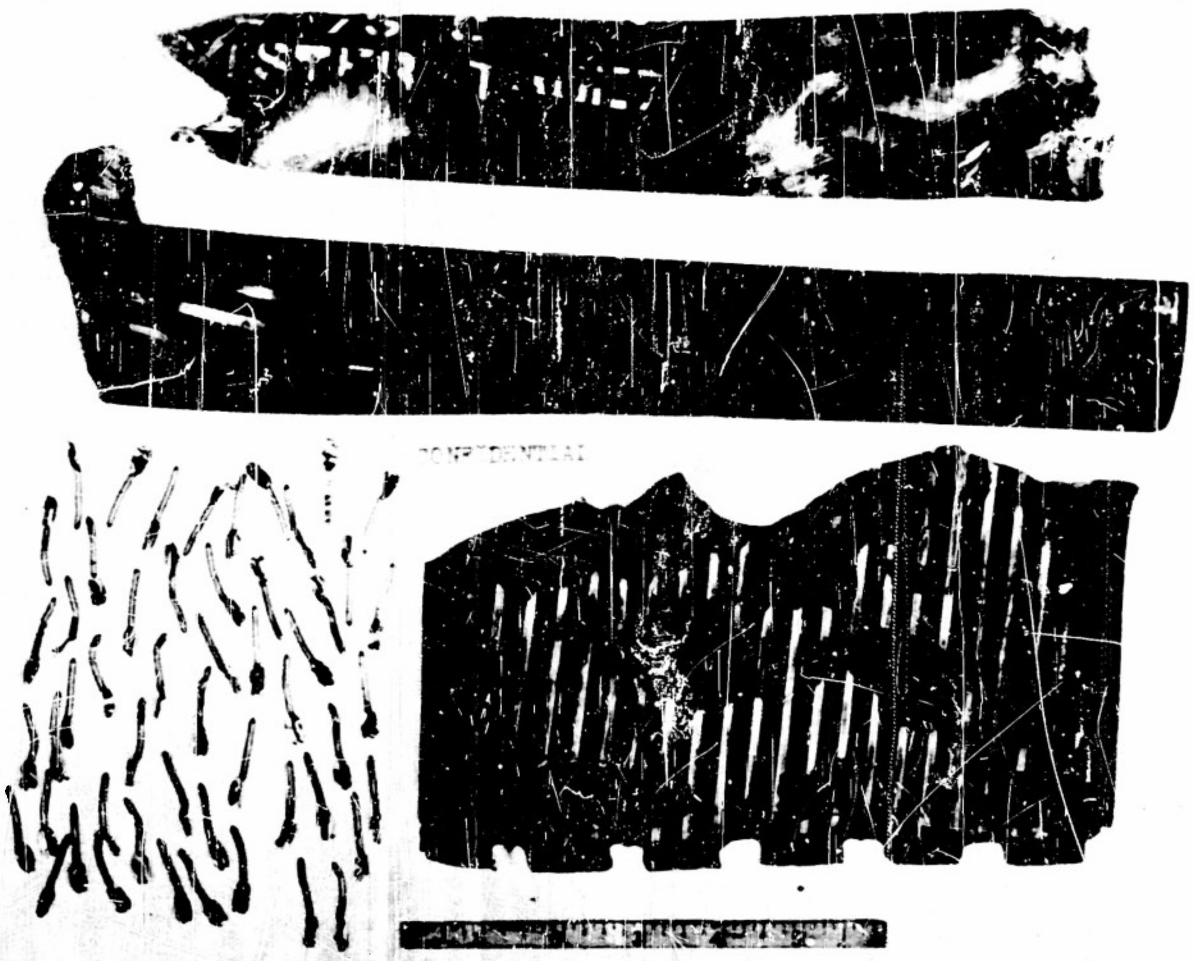

53-2199 20 January 1953 JEFFERSON PROVING GROUND ORDNANCE CORPS

Canister, T30E7, J.P.G. Sample No. 5. Recovered Canister Parts Showing Land Markings and a Sample Group of Recovered Flechettes.

FIG.17

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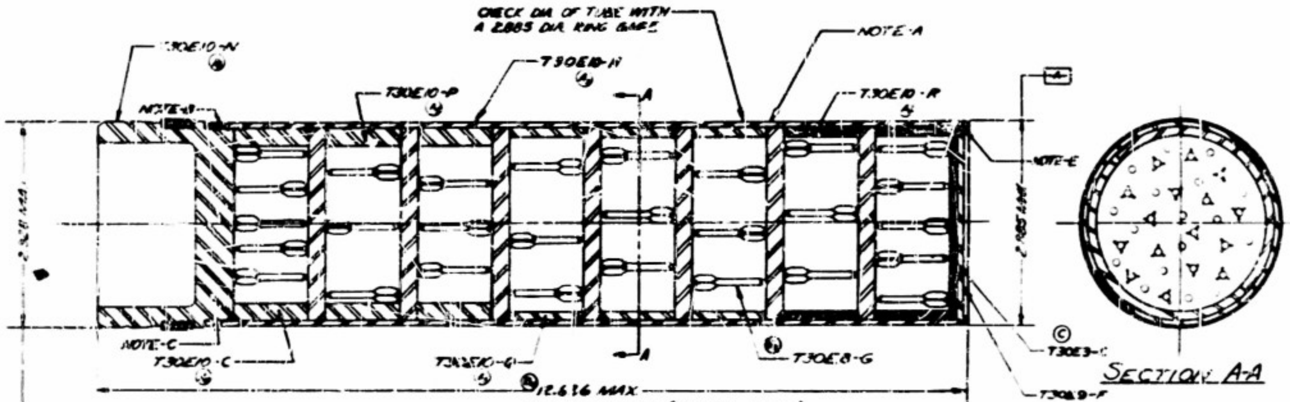

ASSEMBLY (UPPER HALF)

ASSEMBLY ALTERNATIVE (LOWER HALF)

WEIGHT 14.72.5 LBS

TOTAL NUMBER OF FLECHETTES = 4950

NOTES:

A. STENCIL CIRCUMFERENTIALLY ON BASE WITH WHITE MARKING INK AS PER T30E10-M.

B. SECURE BODY TO BASE IN SIX PLACES BY ARC WELDING, FINISH SMOOTH TO ORIGINAL CONTOUR.

C. SILVER SOLDER BODY TO BASE USING BRAZING FLUX. LOCALIZE SOLDERING HEAT. AFTER SOLDERING REMOVE ALL FLUX AND OXIDES FROM EXTERIOR SURFACE. SOLDER MUST FLOW AROUND ENTIRE JOINT.

D. PRIOR TO LOADING WITH FLECHETTES, PREPARE ALL INTERIOR SURFACES OF BODY AND ALL SURFACES OF DISC SUPPORTS, AND STEEL SPACERS IN ACCORDANCE WITH GRADE I, SPEC. [illegible] AND PAINT SURFACES WITH BLACK ENAMEL, NO. 3725.

E. SOLDER CLOSING DISC AROUND ENTIRE END WITH LOW MELTING POINT SOLDER, GRADE A, SPEC QQ-S-571, USING NON-ACID FLUX, SPEC O-F-506.

F. PRIOR TO PAINTING, PREPARE ALL EXTERIOR SURFACES OF BASE AND BODY ASSEMBLY IN ACCORDANCE WITH GRADE I, SPEC [illegible] EXCEPT THAT THE SURFACES ARE TO BE CLEANED FREE OF RUST, SCALE, FLUX OR OTHER CONTAMINATION, BEFORE APPLYING PHOSPHATE COATING. THE PHOSPHATE COATING IS TO BE APPLIED BY SPRAYING ONLY.

G. AFTER ASSEMBLY, PAINT ENTIRE EXTERIOR SURFACE OF CANISTER, EXCEPT ROTATING BAND, WITH BLACK LACQUER ENAMEL, [illegible], SPEC. MIL-E-10687.

H. ASSEMBLE 350 FLECHETTES INTO EACH OF THE BOTTOM THREE LAYERS EACH OF THE REMAINING LAYERS IS TO CONTAIN 660 FLECHETTES. FLECHETTES IN THE BOTTOM [illegible] LAYERS ARE TO BE PAINTED [illegible] FLECHETTES IN THE NEXT 3 LAYERS ARE TO BE PAINTED BLACK FLECHETTES IN THE TOP 2 LAYERS ARE TO REMAIN UNPAINTED.

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CANISTER ASSEMBLY

FULL

FIG. 18